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An introduction to microprocessors

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WE INDICATED last month that you can readily interface, using asynchronous serial techniques, any laboratory instrument with moderate data rates to anyone of a variety of different devices, including a teletypewriter, a minicomputer, a programmable calculator, a microprocessor, a time share terminal, a cathode ray tube terminal, or even a large computer. In this column, we would like to discuss microprocessors, probably the most exciting recent development in the entire field of electronics, and to briefly compare them to programmable calculators for typical laboratory applications.

The best description of what a microprocessor is, and isn't, has been given by Laurence Altman in a recent issue of *Electronics* 1: "A microprocessor is not a computer but only part of one. To make a computer out of a microprocessor requires the addition of memory for its control program, plus input and output circuits to operate peripheral equipment ... What a microprocessor is, then, is the control and processing portion of a small computer or microcomputer. Moreover, it has come to mean the kind of processor that can be built with LSI MOS, or more recently, Bipolar, circuitry, usually on one chip. Like all computer processors, microprocessors can handle both arithmetic and logic data in bit-parallel fashion under control of a program. But they are distinguished both from a minicomputer processor by their use of LSI with its lower power and costs, and from other LSI devices (except calculator chips) by their programmable behavior."

Thus, a microprocessor is not a totally self-contained computer-on-a-chip, nor is it able to compete with and replace the central processing unit (CPU) within a computer. Existing microprocessor chips are simply much too slow for such applications. The niche that microprocessors will soon fill is in the creation of "smart" input/output devices to a computer that relieve that computer of the drudgery associated with the data acquisition from and the control of such devices. In other words, microprocessors will shortly become very important tools in computer interfacing, a trend that will accelerate as the price of microprocessor chips declines, as more individuals develop the capability to handle such chips, and as more manufacturers incorporate such chips in laboratory instruments and other types of devices that communicate with computers.

The advantages of interfacing with microprocessors are at least fourfold:

1. Microprocessor communications are simple. The communications capability of a microprocesspr system is a big point in its favor. Most such systems come with a built-in asynchronous serial port, and thus can communicate with Teletypes or with any device that also has an asynchronous serial port. The microprocessor is not inherently limited to only a single asynchronous port; it is very easy to add more such ports and thus permit the microprocessor system to communicate serially with other external devices, such as laboratory instruments that are interfaced with Analog Devices, Inc., SERDEX modules. Microprocessor systems have parallel input ports for inputs from various sensor instruments, including digital voltmeters, digital panel meters, digital frequency meters, and digital counters. Any type of digital circuit that can supply parallel digital data can be used in conjunction with a microprocessor system.

2. Microprocessor systems are inexpensive. Such systems currently range in price from several hundred dollars to several thousand dollars, depending upon the capability of the system. They are available from Intel, Prolog Corporation, Digital Equipment Corporation, Control Logic, Inc., and other companies. The number of manufacturers that offer microprocessor systems is increasing rapidly.

3. Microprocessor systems are flexible and powerful, Microprocessors have the ability to make decisions. (Is an input value from a digital sensor too high or too low? If it is too high, then

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open a valve and release pressure on the system. If it is too low, then open another valve and add gas to the system.) Microprocessors use software to replace hardware; i.e., microprocessor programs replace complicated hard-wired random logic digital electronic circuits that perform a variety of functions, including sequential logic, non-sequential logic, simple arithmetic calculations, and comparison of digital signals. Manufacturers of microprocessor systems provide you both with read/write memory, for temporary data and program storage, and with read-only memory, which is easily programmed with the aid of a pROM programmer. Once you have written and tested a program, using read/write memory, that can acquire data and perform desired control operations, you can "burn" it into a programmable read-only memory (pROM) integrated circuit chip and then use the chip day after day to operate the microprocessor system. You never have to worry about power failure causing your program to be erased. The program can remain in the pROM for up to twenty years; it is always available for reloading into a read/write memory. The program can be easily modified to accommodate changed data acquisition or control requirements. You can develop a whole repertoire of pROM chips to accomplish different functions (we can easily envision the use of pROM chips for programmed temperature chromatography, multisample and multiparameter analysis of chemical samples, and similar applications).

4. Microprocessor systems are capable of handling most laboratory data acquisition requirements. Current microprocessor systems can acquire digital data at the rate of five hundred 16-bit words/sec. Higher data acquisition rates are occasionally claimed by manufacturers, but they frequently overlook the real software overhead that is needed, for example, to input the data, check if the data are ready, and compare the data to make sure that they are within the right range of values.

In the area of mathematical computations, microprocessors can perform integer multiplications and divisions, i.e., 3 times 4 or 5 divided by 7, with reasonable accuracy. A floating-point package available with the 8-bit Intel microprocessor allows you to perform additions, subtractions, multiplications, and divisions over the range of $\pm 10^{32}$ to $\pm 10^{-32}$. This package requires four read-only memories, which means that 1000 words of your microprocessor are dedicated to the floating-point package. Execution times are slow, so you must worry about the following types of questions: Do you acquire a data point and then operate upon it and still have sufficient time to acquire the next data point? Or must you store a complete block of data and then operate upon the block as a whole? If you store a block of data, how much additional memory is required for the microprocessor? Finally, is the system sufficiently complex and expensive that it can be replaced by a minicomputer or programmable calculator?

The strong point of the microprocessor is that it can perform control functions quickly, easily, and inexpensively. The microprocessor can turn devices on and off. It can regulate physical parameters such as temperature, pressure, velocity, and flow. Since it lacks special functions such as log, x^y, sine, cosine, square root, hyperbolic sine, and hyperbolic cosine, it cannot perform sophisticated mathematical computations. This is one reason why many individuals are looking very seriously at programmable calculators, which start in the vicinity of $3000; are available from Wang, Tektronix, and Hewlett-Packard; and allow one the ability to program with complex functions such as sine, cosine, log, and x^y. The programmable calculators, however, are not nearly as convenient to use as microprocessors in the control of equipment and processes.

As a final point, we would like to caution you about making any long-term decisions concerning both microprocessors and programmable calculators. The comments above apply to today's technology, which is precisely what you can do today. The price/performance ratio changes from day to day, so that a decision that is valid today may not be the same one that would be proper in a month or a year from now; e.g., 8-bit bipolar microprocessors are expected to be announced by Intel by the time that this column goes to press. Cycle times of 50 nsec are expected for such microprocessors. This speed is a little bit difficult to precisely define for the user, but it represents probably a decade of improvement in overall microprocessor speed when compared to any microprocessor available in June 1974.

If you can postpone your problem, you may find that you can solve it differently and/or less expensively a year from now. Digital electronics is without doubt the fastest changing technological field today. You, as a laboratory scientist or engineer, will be a major beneficiary of the changes that are occurring. However, to take proper advantage of the new technology, you will have to spend some time learning the jargon and understanding the tradeoffs that can be made. Microprocessor equipment, if cared for properly, has an operational life of at least ten years but a functional life that may only be several years. A reasonable strategy would be to postpone the purchase of a microprocessor until the price/performance ratio justifies a purchase, and then to go ahead and purchase a system with the knowledge that the same system will probably cost at least 20% less for the same performance a year later. We believe that not too much time will pass before all of us who are involved in research or manufacturing and depend upon instrumentation will have to take advantage of the power of microprocessors if we are to continue to have viable products or research programs. We recommend that you give careful consideration to the ability to interface newly acquired digital instruments to future ones that will come on the market within the next several years. We emphasize again that the existence of asynchronous serial ports on your digital instruments will allow you to hedge your bets for the future.

Reference

1. ALTMAN, L. *Electronics*, 83 (Apr. 18, 1974).